AD-A073 500 NAVAL APPLIED SCIENCE LAB BROOKLYN NY F/G 11/4

FATIGUE PROPERTIES OF HIGH STRENGTH REINFORCED PLASTIC LAMINATE--ETC(U)

FEB 66

UNCLASSIFIED NASL-6427-TM-3 NL

1 OF 1

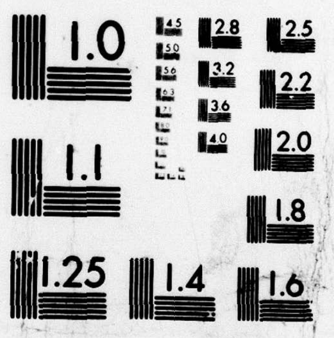
AD A073500

END

DATE FILMED

10-79

DDC


1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

UNCLASSIFIED

1

LEVEL II

AD A073500

DDC FILE COPY

TECHNICAL MEMORANDUM

U.S. NAVAL APPLIED SCIENCE LABORATORY
NAVAL BASE
BROOKLYN, NEW YORK 11251

LEVEL II

1

6 FATIGUE PROPERTIES OF HIGH STRENGTH REINFORCED PLASTIC LAMINATES.

Lab. Project 6427, Technical Memorandum #3

9 Technical ~~Memorandum~~ 1

SF 020-04-01, Task 1008

11 2 February 1966

14 NASL-6427-TM-3

12 14p.

MATERIAL SCIENCES DIVISION

Accession For	
NTIS GRA&I	☒
DDC TAB	☐
Unannounced	☐
Justification	
By Per Hr. on File	
Distribution/	
Availability Codes	
Dist.	Avail and/or special
A	

Approved: D. H. Kallas
D. H. KALLAS
Associate Technical Director

U. S. NAVAL APPLIED SCIENCE LABORATORY
NAVAL BASE
BROOKLYN, NEW YORK 11251

Lab. Project 6427
Technical Memorandum #3

ADMINISTRATIVE INFORMATION

Ref: (a) NAVAPLSCIENLAB Program Summary of 1 Dec 1965, Pages 307 to 320
(b) NAVAPLSCIENLAB Project 6427, Tech Memo #2 of 28 Jun 1965
(c) NAVAPLSCIENLAB Project 6188, Tech Memo #1 of 27 Mar 1964

FIGURES

1 - Photo L19876-3, Typical Large Scale Fatigue Specimen

2 - Photo L19876-6, Typical Ultrasonic Recordings of Large Scale Fatigue Specimen

3 - S-N Curve for Glass Reinforced Plastic Specimens - S Glass with HTS Finish, 2:1 Layup; Stress Cycle - Zero to Maximum Compression

4 - Photo L19876-7, Typical Failure of Large Scale Fatigue Specimen

TABLE

1 - Results of Large Scale Static and Fatigue Tests on S994 HTS Finish Glass Reinforced Plastic

1. The U. S. Naval Applied Science Laboratory, in accordance with reference (a), is conducting an investigation of the low cycle fatigue characteristics of thick, glass reinforced, plastic laminates. Details of background leading to this work and initial results were reported in reference (b). This technical memorandum covers the additional work completed to date.

OBJECTIVE

2. The objective of the work covered by this report was to obtain low cycle fatigue data on a thick high strength glass reinforced plastic laminate under cyclical compression loading with the view of developing procedures for collecting data for a modified Goodman diagram. p.6

DESCRIPTION

3. The material used in these tests was 1 inch thick, glass reinforced, plastic sheet fabricated from S994, HTS finish glass with a 2 by 1 layup. The glass, content of the laminate was approximately 80% by weight.

4. Ten large scale specimens were fabricated from the above material to overall dimensions of 31 in. by 10 in. by 1 in. A photograph of a typical specimen is given in Figure 1. The specimen was reduced to a width of 4 in. at the mid-section to insure that failure occurred in this area. In fabricating the test specimens, the laminate was oriented so that specimens were strongest in the direction parallel to the longitudinal axis.

PROCEDURE

5. Prior to testing, the specimens were examined non-destructively for structural defects and overall quality level using the NAVAPLSCIENLAB automated scanning and recording ultrasonic facility described in reference (c).

6. Static and cyclical loading tests were conducted in the NAVAPLSCIENLAB 300,000 pound hydraulic, variable range, fatigue machine described in detail in reference (b). In order to establish the static compressive strength of the laminate three specimens were subjected to increasing loads until failure occurred and the ultimate loads recorded. The remaining seven specimens were subjected to compressive cyclical loading over the ranges indicated below which are expressed in terms of the average ultimate compressive strength of the first three statically loaded specimens.

No. of Specimens	Range of Loading Percent of Ultimate Compressive Strength
2	0 to 80
2	0 to 75
3	0 to 70

Loading of all specimens was continued until the specimen could no longer sustain the load as evidenced by complete collapse, and the total number of cycles to failure was recorded. The number of cycles to first evidence of failure was also recorded.

RESULTS

7. Ultrasonic inspection of samples prior to testing revealed no significant structural defects at the critical section of any of the specimens, although slight edge delamination was noted in the outer plies of several specimens which may be attributable to machining. Void content was estimated from ultrasonic attenuation recordings based on the technique described in reference (c). Typical recordings are shown in Figure 2. In this figure two

traces are shown which were made at different critical attenuation levels. Each level allows printing when the material's attenuation is below the indicated value. There is no print-out above this level. From these recordings it is estimated that the critical level representative of the quality of the material would be 13 db. This critical attenuation level, a, is used to determine absorption attenuation, A, by the following formula, where t is thickness in inches.

$$A = \frac{a - 4.6}{t} \text{ db/in.}$$

Thus, for a critical level of 13 db, the absorption attenuation is 8.4 db/in. Also, from reference (c), void content, V, may be calculated from:

$$V = 0.139A - 0.63$$

In this case void content is:

$$V = 0.139(8.4) - 0.63 = 0.54\%$$

All of the specimens evaluated had void contents below 1% by volume. These nondestructive test results indicate uniformity among specimens and a relatively good quality level for all specimens.

8. The results of static and cyclical compression loading are given in Table 1. The average ultimate compressive strength for the three statically loaded specimens is 69,000 psi and ultimate failure in each case was by transverse shear. Under cyclical compression loading the first indication of failure manifested itself as either delamination near the surface or transverse shear at localized areas in the reduced section. As cycling was continued, progressive damage was predominantly in shear until complete collapse occurred by this mode of failure. As seen from Table 1 first indication of failure occurred long before complete failure. First indication of failure occurred at 1 cycle for specimen 8-2 but ultimate failure did not occur at the same location.

9. The results of Table 1 are shown plotted in Figure 3 on semi-log coordinate paper. The scale of the ordinate, representing cyclical, zero to compression loading, is based on percent of ultimate compressive strength. The three points shown at 0.5 cycles represent the static compressive strength for three specimens and fall above and below the 100 percent point which represents the average of the same three specimens. The remaining

points plotted on Figure 3 represent lives under various zero to compression ranges. A straight line has been drawn through the points to indicate the trend of results. One specimen loaded cyclically to 70 percent of average compressive strength did not fail after 300,000 cycles compared to approximately 34,000 cycles for two other specimens under the same loading. Static loading of this specimen gave an ultimate compressive strength of 87,000 psi which is much higher than the average of 69,000 psi established on three specimens. No apparent cause for the anomalous behavior of this specimen could be determined.

DISCUSSION

10. As indicated in results, progressive failure started primarily by shear at an angle to the face of the specimen and continued until the specimen collapsed completely. Although delamination was noted in several specimens the ultimate mode of failure was in shear. It was at first thought that data at which first indication of failure occurred could be plotted on the S-N curve. However, it was found in some instances that these indications would not progress and that ultimate failure occurred elsewhere. Therefore, an indication of failure which does not contribute to ultimate failure can not properly be classified as a first indication and plotted with those that progress to ultimate collapse.

11. It appears that the most consistent criterion of failure for low cycle fatigue of specimens under compression loading is complete collapse. The end point is definite and does not involve any measurements of deformation.

12. Since the mode of failure under static and cyclical compression loading is the same in both cases and since the low cycle S-N curve is usually found to be a straight line on semi-log coordinate paper, collection of data at two judiciously chosen points should permit determination of the desired S-N curve. One of these points should be the ultimate static strength in compression and the other point should be a loading which will give a life of approximately 10,000 cycles. Based on results of Figure 3 a cyclical compression loading of zero to 75 percent of ultimate strength should be selected to give this approximate life. A minimum of 5 specimens should be tested at each point. A similar procedure may be used for zero to tension loading. Stress range for alternating stresses would follow from the trend of results of the zero to compression and zero to tension loading. If 10 specimens are used to determine the low cycle S-N curve for alternating stresses, it follows that 30 specimens is the minimum number needed for determining a modified Goodman diagram.

CONCLUSIONS

~~13.~~ Available facilities and procedures are suitable for determining low cycle S-N diagrams for thick high strength glass reinforced laminates under various ranges of stress.

14. A modified Goodman diagram may be determined with a minimum of 30 specimens.

FUTURE WORK

15. Eighteen large scale fatigue specimens fabricated from material procured from Minnesota Mining and Manufacturing Company will be subjected to low cycle fatigue loading under various ranges for the purpose of establishing a modified Goodman diagram for the material.

16. Additional identical material will be procured to permit obtaining sufficient data to complete the above diagram.

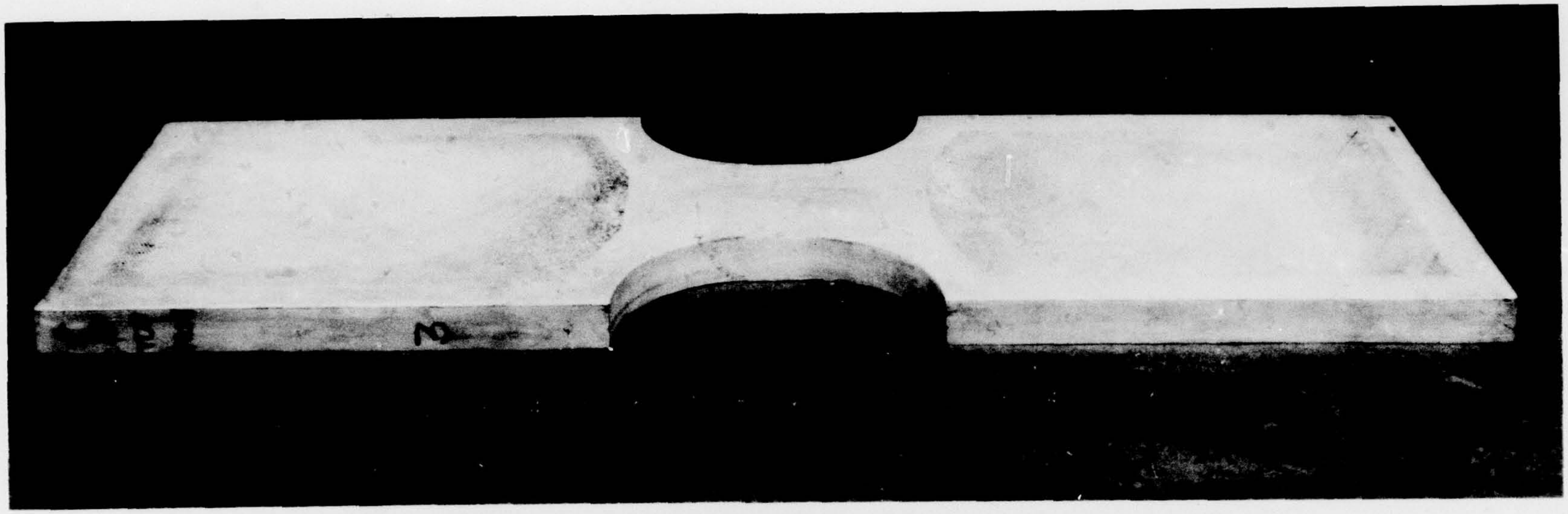
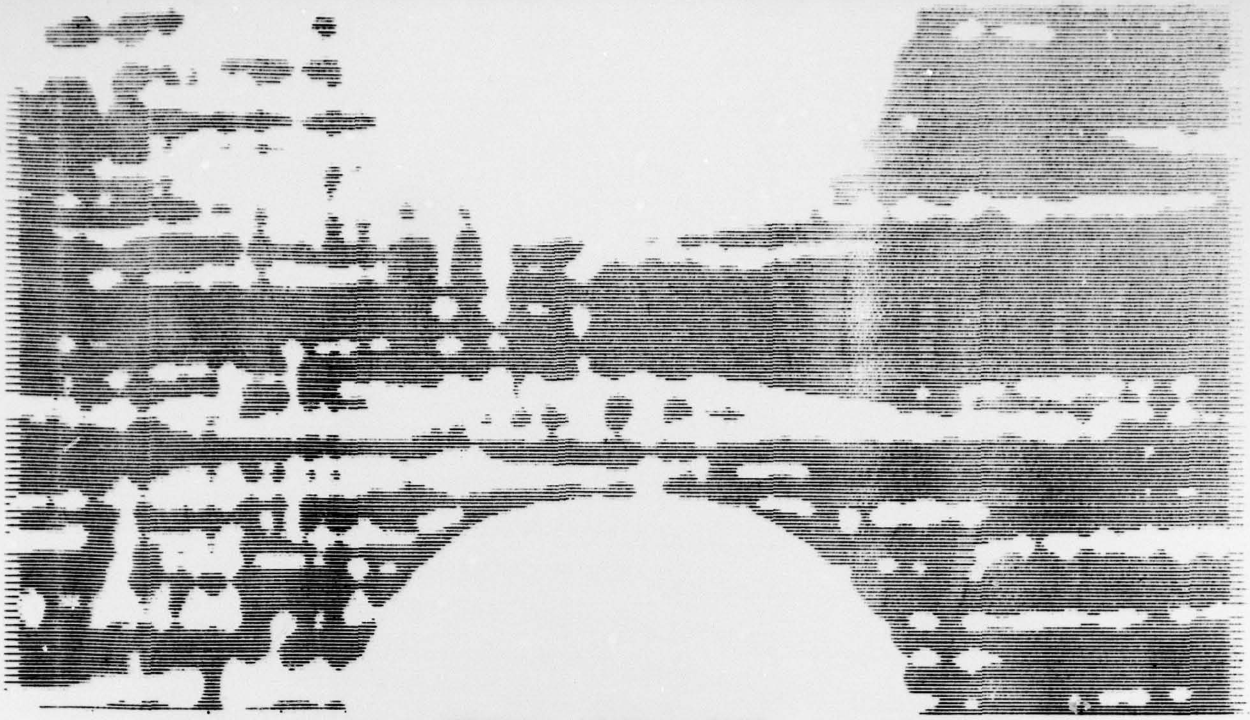


PHOTO L 19876-3

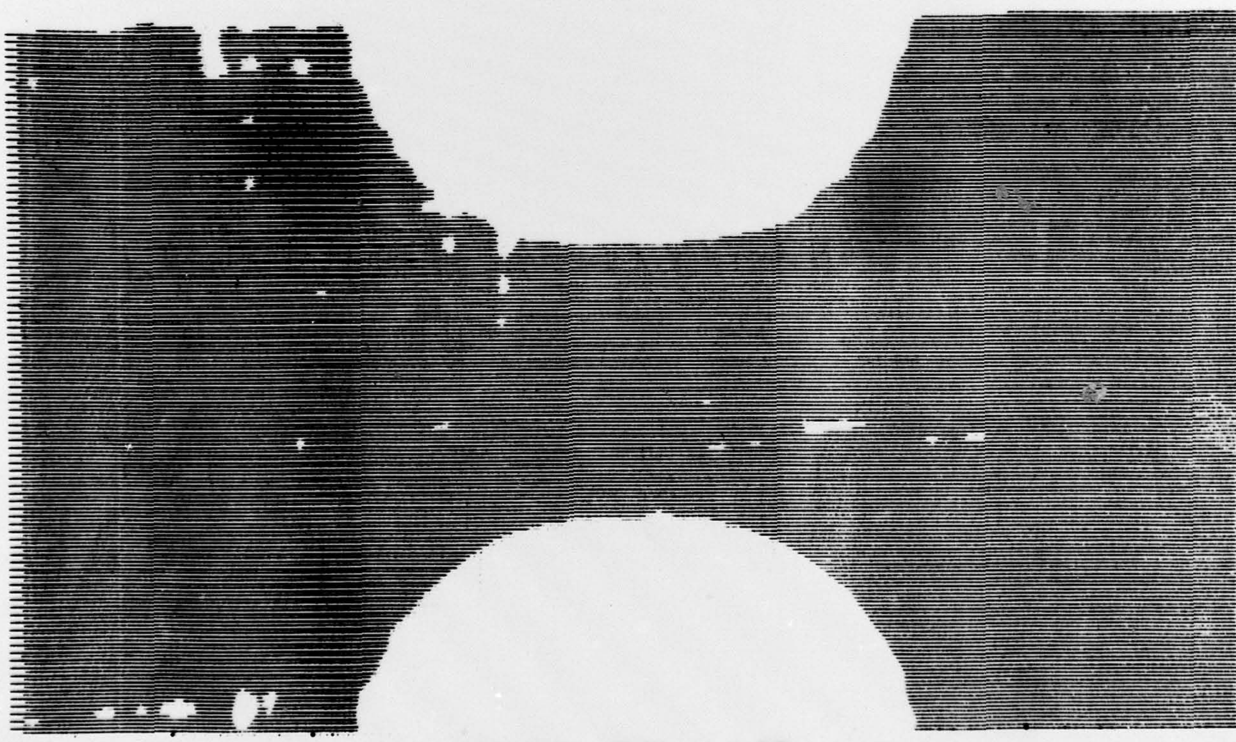
FIGURE 1 - TYPICAL LARGE SCALE FATIGUE SPECIMEN

U.S. NAVAL APPLIED SCIENCE LABORATORY

LAB. PROJECT 6427
TECHNICAL MEMORANDUM 3



CRITICAL LEVEL – 12 DB



CRITICAL LEVEL – 14 DB

PHOTO L 19876-7

FIGURE 2 - TYPICAL ULTRASONIC RECORDINGS OF LARGE SCALE FATIGUE SPECIMEN

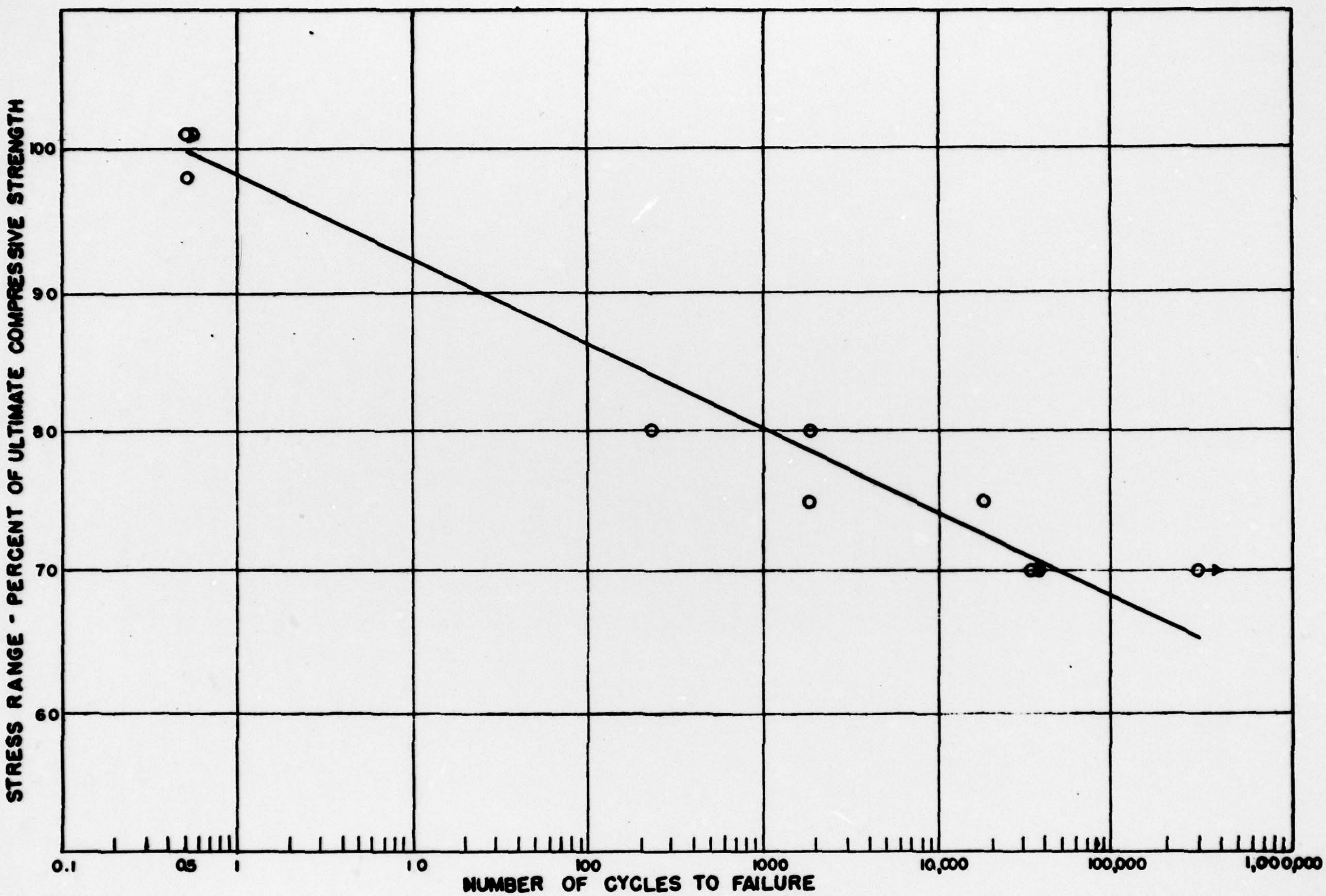


FIGURE 3 - S-N CURVE FOR GLASS REINFORCED PLASTIC SPECIMENS - E GLASS WITH HTS FINISH; 2:1 LAYUP STRESS CYCLE - ZERO TO MAXIMUM COMPRESSION

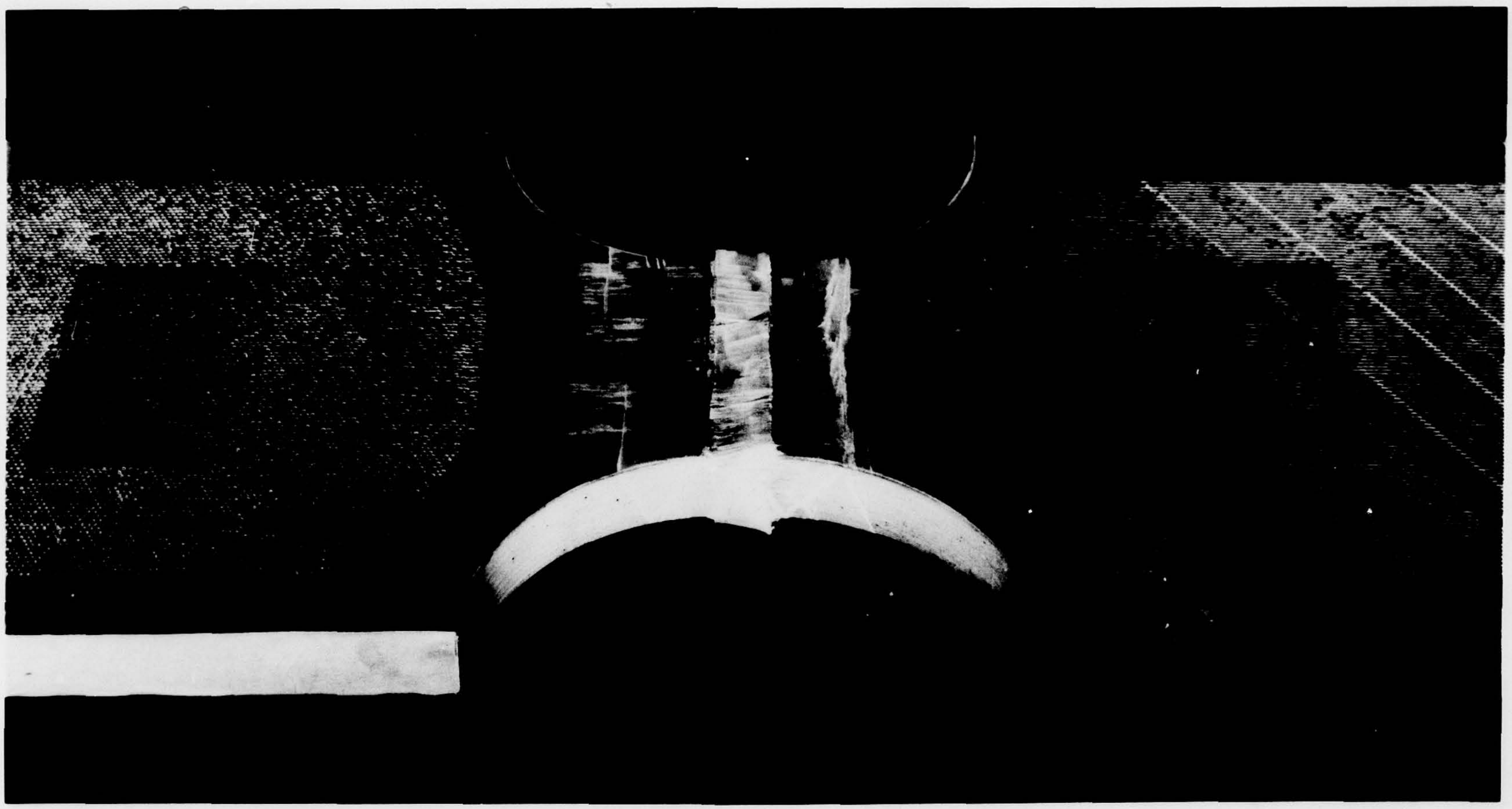


PHOTO L19876-6

FIGURE 4 - TYPICAL FAILURE OF LARGE SCALE FATIGUE SPECIMEN

U.S. NAVAL APPLIED SCIENCE LABORATORY

LAB. PROJECT 6427
TECHNICAL MEMORANDUM 3

TABLE 1

RESULTS OF LARGE SCALE STATIC AND FATIGUE TESTS ON S994 HTS FINISH GLASS REINFORCED PLASTIC

Static Compression Loading

Specimen No.	Nominal Ultimate Stress psi	Nominal Stress at First Signs of Failure psi	Mode of Failure
7-1	69,700	55,500	Transverse shear in test section
8-1	67,600	58,600	Transverse shear in test section
6-2	69,800	36,700	Transverse shear in test section and surface delamination

Cyclical Compression Loading

Specimen No.	Maximum Nominal Stress psi	Percent of Average Ultimate Stress	No. of Cycles To Ultimate Failure	No. of Cycles To First Indication of Failure	Mode of Failure
8-2	55,200	80	1,860	1	Transverse shear in test section
4-1	55,200	80	230	130	Transverse shear in test section
8-3	51,750	75	1,810	300	Transverse shear in test section
4-3	51,750	75	17,100	760	Transverse shear in test section
7-2 4-2	48,300 48,300	70 70	33,800 34,000	7,000 2,900	Transverse shear and delamination in test section
6-1	48,300	70	300,000+	25,500	Transverse shear in test section